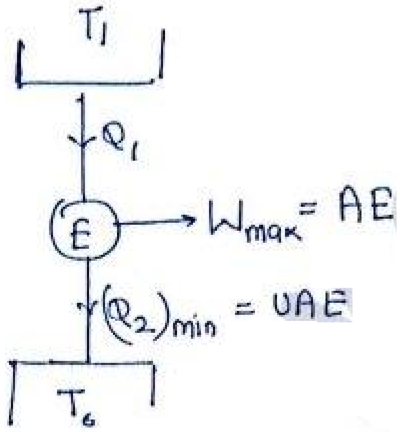
Available Energy & Unavailable Energy

Available Energy:- It is the maximum amount of work that can be extracted from a certain heat input in a cycle.

Unavailable Energy:- It is the minimum amount of heat that has been rejected to the sink.



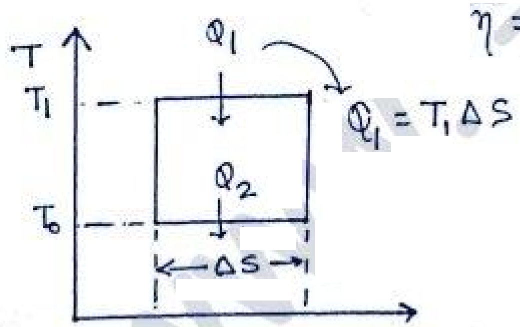
$$Q_1 = W + Q_2$$

$$(W)_{max} = Q_1 - (Q_2)_{min}$$

$$\eta = 1 - \frac{T_L}{T_H}$$

(a) $T_L = \text{Const.}$, $T_H \uparrow \rightarrow \eta \uparrow$ {upto limit of turbine blade

(b) $T_H = \text{Const}$, $T_L \downarrow \rightarrow \eta \uparrow$ {upto limit of atmosphere Cond^n



$$\eta = 1 - \frac{T_0}{T_1} = \frac{W_{max}}{Q_1}$$

$$W_{max} = Q_1\left(1 - \frac{T_0}{T_1}\right)$$

$$W_{max} = Q_1 - T_0\left(\frac{Q_1}{T_1}\right)$$

$$\boxed{W_{max} = Q_1 - T_0 \Delta S}$$

$$AE = Q_S - Q_R = Q_S - UAE$$

$$\boxed{UAE = T_0 \Delta S}$$

Que:- 1000kJ of heat is supplied to a reversible heat engine from a sourse maintain at 327°c and the sink temp is 27°c then determine AE & UAE.

Sol^n

$$1 - \frac{T_L}{T_H} = \frac{W_{max}}{Q_1} = 1 - \frac{300}{600}$$

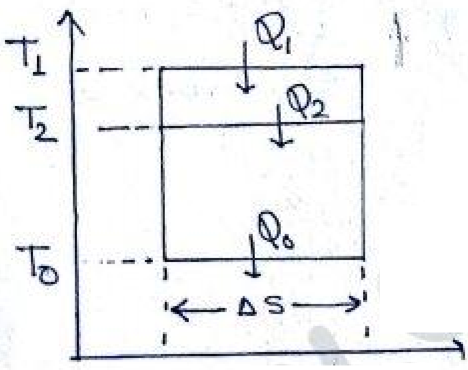
$$W_{max} = 1000 \times \frac{1}{2}$$

$$AE \quad W_{max} = 500 \text{ kJ}$$

$$UAE = 1000 - 500$$

$$UAE = 500 \text{ kJ}$$

Loss of Available energy when the same heat is transferred through a finite temp. difference



$$\eta = \frac{\text{output}}{\text{Input}} = \frac{W_{net}}{Q_S} = \frac{Q_{net}}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$\eta = 1 - \frac{Q_R}{Q_S}$$

(a) Q_R = Constant

$Q_S \uparrow$

$$\eta \uparrow = \left(1 - \left(\frac{Q_R}{Q_S \uparrow}\right)\downarrow\right)$$

$$Q_1 = T_1 \Delta S$$

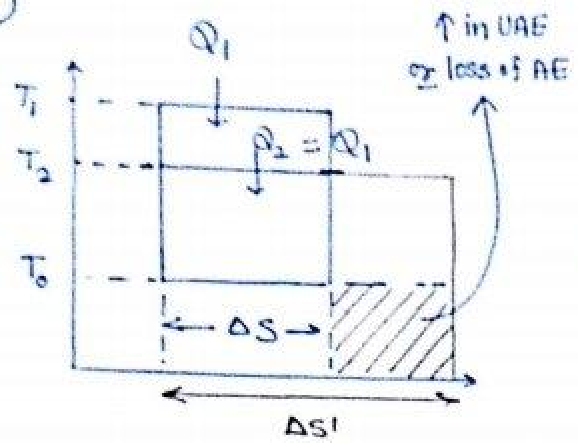
$$Q_2 = T_2 \Delta S$$

$$Q_0 = T_0 \Delta S = Q_R = \text{Const.}$$

$$T_1 > T_2$$

$$T_1 \Delta S > T_2 \Delta S \Rightarrow \boxed{Q_1 > Q_2}$$

(b)



$$\eta = 1 - \frac{Q_R}{Q_S}$$

$Q_S = \text{Const.}$

$Q_R \uparrow$

$$\downarrow \eta = 1 - \frac{Q_R}{Q_S}$$

$$Q = (\uparrow) T \Delta S (\downarrow)$$

$$Q_1 = T_1 \Delta S \quad , \quad Q_2 = T_2 \Delta S'$$

$$Q_1 = Q_2$$

$$T_1 > T_2$$

$$\Delta S < \Delta S'$$

Q_R → Q_1 at T_1 $\Rightarrow$ $Q_0 = T_0 \Delta S$

Q_R → Q_1 at T_2 $\Rightarrow$ $Q_0 = T_0 \Delta S'$

$$\Delta S' > \Delta S$$

$$T_0 \Delta S' > T_0 \Delta S$$

$$(Q_R)_{Q_1 \text{ at } T_2} > (Q_R)_{Q_1 \text{ at } T_1}$$ → now go effi

$$(\eta)_{Q_1 \text{ at } T_2} < (\eta)_{Q_1 \text{ at } T_1}$$

$$\left(\frac{AE}{Q}\right)_{\text{at } T_2} < \left(\frac{AE}{Q}\right)_{\text{at } T_1} \Rightarrow \boxed{(AE)_{T_2} < (AE)_1}$$

$$\uparrow \text{in UAE} = T_0(\Delta S' - \Delta S)$$

$$Q_1 = T_1 \Delta S \Rightarrow \Delta S = \frac{Q_1}{T_1}$$

$$Q_1 = T_2 \Delta S' \Rightarrow \Delta S' = \frac{Q_2}{T_2}$$

$$\text{So } \uparrow \text{in UAE} = T_0\left[\frac{Q_1}{T_2} - \frac{Q_1}{T_1}\right]$$

Imp

$$\boxed{\text{Increase in UAE or loss in AE} = \frac{T_0 Q_1 (T_1 - T_2)}{T_1 T_2}}$$

Note:- Greater the temp. differance, more will be the loss of AE. Therefore same heat is having more importance at higher temp in comparison to the lower temp

Availibility :- It is the maximum useful work that can be obtain in which system comes in equilibrium with dead state in a process.

Initial State $\underline{P_1, T_1, h_1, u_1, S, V_1}$

Final state $\underline{P_0, T_0, h_0, u_0, S_0, V_0}$

Dead State / Atmospheric state / Ambient State / surrounding State / Reference or detum State

Close System :-

Useful work :- $Tds = du + Pdv$

$$Tds = du + (U.W.)$$

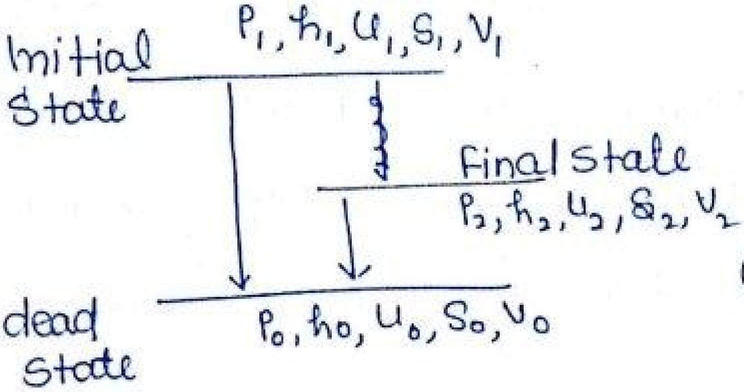
$$U.W. = Tds - du$$

$$(U.W.) = T(S_F - S_I) - (u_F - u_I)$$

$$(U.W) = T_0(S_0 - S_1) - (u_0 - u_1)$$

Useful work Close System

$$\boxed{U.W. = (u_1 - u_0) - T_0(S_1 - S_0)}$$



$(1-0)$

$$(u_1 - u_0) - T_0(S_1 - S_0)$$

$(2-0)$

$$(u_2 - u_1) - T_0(S_2 - S_0)$$

$$(1-2) \rightarrow (u_1 - u_2) - T_0(S_1 - S_2)$$

$$\boxed{(U.W)_{CS} = (u_I - u_F) - T_0(S_I - S_F)}$$

maximum useful work:-

I.S. P_1, U_1, h_1, S_1, V_1

F.S. P_0, U_0, h_0, S_0, V_0

$$(M.U.W.)_{C.S} = \left[(u_1 - u_0) - T_0(S_1 - S_0)\right] - P_0 dV$$

$$= (u_1 - u_0) - T_0(S_1 - S_0) - P_0(V_F - V_I)$$

$$= (u_1 - u_0) - T_0(S_1 - S_0) - P_0(V_0 - V_I)$$

$$= (u_1 - u_0) - T_0(S_1 - S_0) + P_0(V_1 - V_0)$$

$$\boxed{(M.U.W)_{close\ syst} = (u_I - u_F) - T_0(S_I - S_F) + P_0(V_I - V_F)}$$

it is always less then (U.W)

Open System :-

Useful work :-

$$(U.W)_{O.S} = (h_I - h_F) - T_0(S_I - S_F)$$

maximum useful work

$$(M.U.W)_{O.S.} = (h_I - h_F) - T_0(S_I - S_F)$$

Note :- The expression of useful work and maximum useful work is same for open system.

Flow Availibity / Availibility Function :-

change in availibity function represent the maximum useful work

Close System :-

$$(MUW)_{C.S.} = (u_1 - u_2) - T_0(S_1 - S_2) + P_0(V_1 - V_2)$$

$$= u_1 - u_2 - T_0 S_1 + T_0 S_2 + P_0 V_1 - P_0 V_2$$

$$= (u_1 + P_0 V_1 - T_0 S_1) - (u_2 + P_0 V_2 - T_0 S_2)$$

$$(MUW)_{C.S.} = \phi_1 - \phi_2$$

$$\boxed{\phi = u + P_0 V - T_0 S}$$

Open system :-

$$(MUW)_{o.s.} = (h_1 - h_2) - T_0(S_1 - S_2)$$

$$= (h_1 - T_0 S_1) - (h_2 - T_0 S_2)$$

$$(MUW)_{o.s.} = \phi_1 - \phi_2$$

$$\cancel{(MUW)_{o.s.}} \quad \boxed{(\phi)_{o.s.} = h - T_0 S}$$

Irreversibility :- It is defined as the diff. between maximum work and actual work

Gouy's stodala theorem :- According to this theorem rate of irreversibility is directly proportional to rate of entropy Generation.

$$\dot{I} \propto (d\dot{s})_{uni}$$

$$\cancel{\dot{I}\ \alpha} \quad \boxed{\dot{I} = T_0 (d\dot{s})_{univ.}}$$

$$\dot{I} = T_0 \left(\Delta S_{System} + \Delta S_{surrounding} \right)$$

PMM-2 :- PMM-2 is impossible because it voilets second law of thermodynamics

i.e. Complate conversion of law grade energy into high grade is impossible

PMM-3 :- It is impossible to construct a device which runs complately in the absense of friction.

Third law of Themodynamics :-

It is impossible to achieve absoulate zero temp (0 K) in a finite number of process.

Nernst Simon statement :- The entropy of a perfect crystalline substance is zero at absoulate zero temp.

Compressibility Factor (z) =

It represent the deviation in the behavior of actual gas from ideal gas.

The mathematical repersentation of compressibility Factor is $z = \frac{PV}{RT}$

$\boxed{\begin{array}{l} z = 1 \text{ (ideal Gas)} \\ z \gtrless 1 \text{ (Real Gas)} \end{array}}$

Gibbs Function (G) :-

$$G = H - TS$$

change in Gibbs function (dG)

$$dG = dH - Tds - s\,dT$$

$$Tds = dH - Vdp$$

$$dH - Tds = Vdp$$

$$\boxed{dG = Vdp - s\,dT}$$

during phase chang Gibbs function remain Constant because $dT = 0$, $dp = 0$.

Gibbs Helmholt Function (F) :-

$$F = U - TS$$

change in Gibbs helmholt function

$$dF = dU - Tds - s\,dT$$

$$Tds = du + Pdv$$

$$-Pdv = du - Tds$$

$$\boxed{dF = -Pdv - s\,dT}$$

CH-5

(33) Aavailability = Useful work open system

$$U.W. = (h_I - h_F) - T_0(S_I - S_F)$$

$$= (400 - 100) - 300(1.1 - 0.7)$$

$$= 300 - 300 \times 0.4$$

$$U.W. = 300 \times 0.6 = 180 \text{ KJ/kg}.$$

(34) H.T. = 1000 W

$T_1 = 400K$, $T_2 = 300k$ $T_0 = 298\ k$

$$(S)_{gen} = 0$$

$$ds = \frac{dQ}{T}$$

$$(\dot{I}) = T_0 \, d\dot{s}$$

$$= 298\left[\frac{-1000}{400} + \frac{1000}{300}\right]$$

$$I = 248.33 \text{ W}$$

(32) $\uparrow$ in UAE $= \dfrac{T_0 Q (T_1 - T_2)}{T_1 T_2} = 250 \text{ kJ}$

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$d = 0.1\ m$ $\qquad T_0 = 298\ K$

$T_1 = 473\ K$

$273 - 200 = 73$

$\rho = 2700\ kg/m^3$

$C = 0.9\ KJ/kgK$

$= \quad (\dot{I}) = T_0 (d\dot{s})$

$V = \frac{4}{3}\pi\left(\frac{0.1}{2}\right)^3 = 5.23\times10^{-4}\ m^3$

$\cancel{I = -298(0.5878)}$

$m = \rho V = 1.4137\ kg.$

$\cancel{= -175.17\ KJ}$

$ds = \frac{dQ}{T}$

$\dot{I} = T_0\left((ds)_{Al} + (ds)_{surr}\right)$

$ds_{Al} = mC_v \frac{dT}{T}$

$ds_{Al} = mC_v\left(\cancel{T_F} - T\ \ln\left(\frac{T_F}{T_I}\right)\right)$

$= T_0\left((ds)_{Al} + \frac{dQ}{T}\right)$

$ds_{Al} = 1.4137\times0.9\ \ln\left(\frac{298}{473}\right)$

$= 298\left(-0.5875 + \frac{222.65}{298}\right)$

$(ds)_{Al} = -0.5878$

$dQ = mC\Delta T$

$= 1.4137 \times 0.9\ (200-25)$

$\boxed{I = 47\ KJ}$

$dQ = 222.65\ KJ$

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$V = 10\ m^3$

$V_A = 6\ m^3 \quad P_A = 6\ bar,\ T_A = 600\ K$

$V_B = 4\ m^3$ vaccum

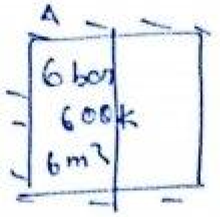
$T_0 = 300\ K$

$P_0 = 1\ bar$

Air $C_v = 0.718\ KJ/KgK$

$ds = \cancel{0.718\times\ln\left(\frac{300}{600}\right)} + 0.287\ \ln\left(\frac{10}{6}\right)\times m$

$ds = m(0.287)\ \ln\left(10/6\right)$



$$I = T_0\left[(ds)_{sys} + (ds)_{surr}\right]$$

$$dQ = 0,\ (ds)_{surr} = 0$$

$$\Delta T = 0$$

$$Tds = \overset{0}{\cancel{du}} + Pdv$$

$$(ds)_{sys} = \frac{P}{T}\,dv$$

$$= R\int \frac{dv}{v}$$

$$(ds) = R\ln\frac{V_F}{V_I}$$

$$I = T_0\, m R \ln\left(\frac{V_F}{V_I}\right)$$

$$I = T_0 \frac{P_A V_A}{\cancel{R}\, T_A} \times \cancel{R} \ln\left(\frac{V_F}{V_I}\right)$$

$$= \frac{600 \times 6}{600} \times 300 \ln\left(\frac{10}{6}\right) = 914.48\ kJ$$

(38) MUW

$P_1 = 9$ bar, $T_1 = 400K$

$P_2 = 1.5$ bar, $T_2 = 300K$

$P_{atm} = P_0 = 1$ bar.

$T_0 = 288K$

$$UW = (U_1 - U_2) - T_0(S_1 - S_2)$$

$$= C_v(T_1 - T_2) - T_0(S_1 - S_2)$$

$$UW = 0.718(400 - 30) - 300(S_1 - S_2)$$

$$ds = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

$$= 1.005 \ln \frac{300}{400} - 0.287 \ln \frac{1.5}{9}$$

$$S_2 - S_1 = 0.225 \text{ kJ/kgK}$$

$$S_1 - S_2 = -0.225 \text{ kJ/kgK}$$

$$UW = 0.718(400-300) - 288(-0.225)$$

$$\underline{UW} = 136 \text{ kJ/kg}$$

$$\max UW = 136 + P_0(V_1 - V_2)$$

$$= 136 + P_0\left[\frac{RT_1}{P_1} - \frac{RT_2}{P_2}\right]$$

$$= 136 + 1 \times 0.287\left[\frac{400}{9} - \frac{300}{1.5}\right]$$

$$\underline{MUW} = 91.6 \text{ kJ/kg}$$

(T4)

$h_i = 4142$ KJ/kg.

$h_e = 2500$ KJ/kg.

open system

$\varphi = h - T_0 S$

$\varphi_1 = h_1 - T_0 S_1 = 1850$ KJ/kg $\quad T_0 = 300$ K

$\varphi_2 = h_2 - T_0 S_2 = 140$ KJ/kg.

$\Rightarrow h_1 + \cancel{KE} + \cancel{PE} + \cancel{Q} = h_2 + \cancel{KE} + \cancel{PE} + W$

$W_{actual} = h_1 - h_2 = 4142 - 2500$

$W_{actual} = 1642$ KJ/kg

$MUW = \varphi_1 - \varphi_2$

$= 1850 - 140$

$MUW = 1710$ kg/kg.

$(MUW)_{os} = (h_1 - h_2) - T_0(S_1 - S_2)$

$1710 = 1642 - 300(S_1 - S_2)$

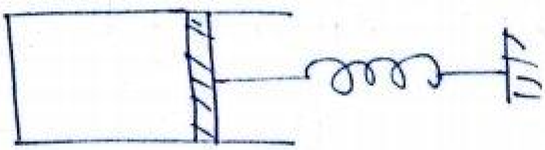
$S_1 - S_2 = -0.226$

$S_2 - S_1 = 0.226$ KJ/kg.

T6

$A = 0.2\,m^2$

Air



$T_1 = 300K$

$V_1 = 0.002 m^3$

$V_2 = 0.003 m^3$

$A = 0.2 m^2$

$K = 10\ kN/m$

$P_{atm} = 100 kPa$

$P_2 = ?$

$\Delta S = ?$

$V_2 - V_1 = A_p x$

$0.001 = 0.2 x$

$x = 0.05 m$

$P_2 = 100 + P_{sp}$

$P_{sp} = \frac{10 x}{0.2} = \frac{10 \times 0.05}{0.2} = 2.5 kPa$

$P_2 = 12.5 kPa$

$$ds = C_v \ln\left(\frac{T_F}{T_I}\right) + R \ln\left(\frac{V_2}{V_1}\right)$$

$$= 0.718 \left(\ln\left(\frac{562.5}{300}\right) + R \ln\left(\frac{3}{2}\right)\right)$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$= \cancel{1.346}$

$$T_2 = \frac{P_2 V_2}{P_1 V_1} \times T_1$$

$ds = 0.451 + 0.116$

$ds = 0.567\ kJ/kgK$

$$ds = C_p \frac{dv}{v} + C_v \frac{dP}{V}$$